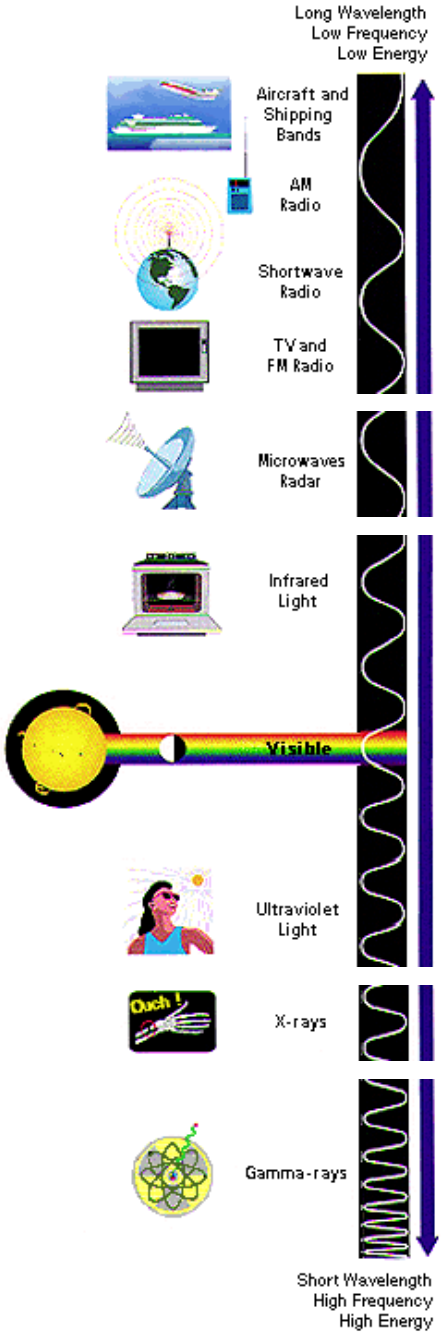
Electromagnetic Spectrum - Introduction

Measuring the electromagnetic spectrum

You actually know more about it than you may think! The electromagnetic (EM) spectrum is just a name that scientists give a bunch of types of radiation when they want to talk about them as a group. Radiation is energy that travels and spreads out as it goes-- visible light that comes from a lamp in your house and radio waves that come from a radio station are two types of electromagnetic radiation. Other examples of EM radiation are microwaves, infrared and ultraviolet light, X-rays and gamma-rays. Hotter, more energetic objects and events create higher energy radiation than cool objects. Only extremely hot objects or particles moving at very high velocities can create high-energy radiation like X-rays and gamma-rays.

Here are the different types of radiation in the EM spectrum, in order from lowest energy to highest:



Radio: Yes, this is the same kind of energy that radio stations emit into the air for your boom box to capture and turn into your favorite Mozart, Madonna, or Justin Timberlake tunes. But radio waves are also emitted by other things ... such as stars and gases in space. You may not be able to dance to what these objects emit, but you can use it to learn what they are made of.

Microwaves: They will cook your popcorn in just a few minutes! Microwaves in space are used by astronomers to learn about the structure of nearby galaxies, and our own Milky Way!

Infrared: Our skin emits infrared light, which is why we can be seen in the dark by someone using night vision goggles. In space, IR light maps the dust between stars.

Visible: Yes, this is the part that our eyes see. Visible radiation is emitted by everything from fireflies to light bulbs to stars ... also by fast-moving particles hitting other particles.

Ultraviolet: We know that the Sun is a source of ultraviolet (or UV) radiation, because it is the UV rays that cause our skin to burn! Stars and other "hot" objects in space emit UV radiation.

X-rays: Your doctor uses them to look at your bones and your dentist to look at your teeth. Hot gases in the Universe also emit X-rays .

Gamma-rays: Radioactive materials (some natural and others made by man in things like nuclear power plants) can emit gamma-rays. Big particle accelerators that scientists use to help them understand what matter is made of can sometimes generate gamma-rays. But the biggest gamma-ray generator of all is the Universe! It makes gamma radiation in all kinds of ways.

A Radio Wave is not a Gamma-Ray, a Microwave is not an X-ray ... or is it?

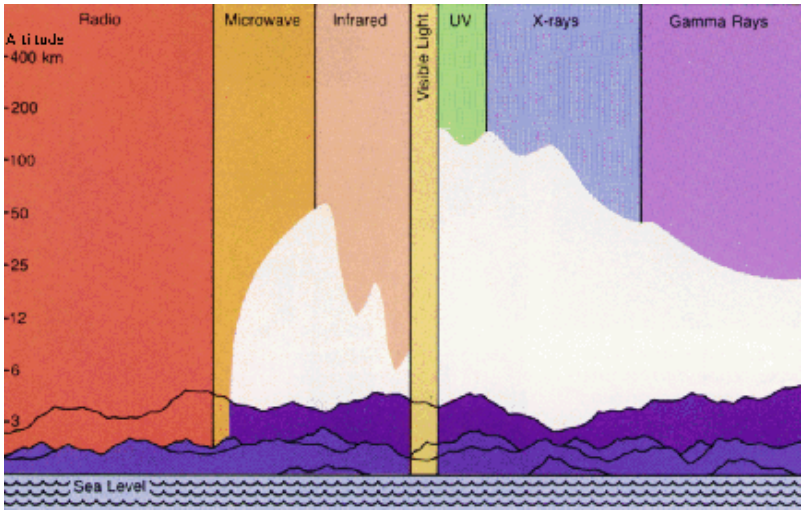
We may think that radio waves are completely different physical objects or events than gamma-rays. They are produced in very different ways, and we detect them in different ways. But are they really different things? The answer is 'no'. Radio waves, visible light, X-rays, and all the other parts of the electromagnetic spectrum are fundamentally the same thing. They are all electromagnetic radiation.
Electromagnetic radiation can be described in terms of a stream of photons, which are massless particles each traveling in a wave-like pattern and moving at the speed of light. Each photon contains a certain amount (or bundle) of energy, and all electromagnetic radiation consists of these photons. The only difference between the various types of electromagnetic radiation is the amount of energy found in the photons. Radio waves have photons with low energies, microwaves have a little more energy than radio waves, infrared has still more, then visible, ultraviolet, X-rays, and ... the most energetic of all ... gamma-rays.

Actually, the electromagnetic spectrum can be expressed in terms of energy, wavelength, or frequency. Each way of thinking about the EM spectrum is related to the others in a precise mathematical way. So why do we have three ways of describing things, each with a different set of physical units? After all, frequency is measured in cycles per second (which is called a Hertz), wavelength is measured in meters, and energy is measured in electron volts.

The answer is that scientists don't like to use big numbers when they don't have to. It is much easier to say or write "two kilometers or 2 km" than "two thousand meters or 2,000 m". So generally, scientists use whatever units are easiest for whatever they are working with. In radio astronomy, astronomers tend to use wavelengths or frequencies. This is because most of the radio part of the EM spectrum falls in the range from about 1 cm to 1 km (30 gigahertz (GHz) to 100 kilohertz (kHz)). The radio is a very broad part of the EM spectrum. Infrared astronomers also use wavelength to describe their part of the EM spectrum. They tend to use microns (or millionths of meters) for wavelengths, so that they can say their part of the EM spectrum falls in the range 1 to 100 microns. Optical astronomers use wavelengths as well. Scientists use both angstroms (0.00000001 cm, or 10^{-8} cm in scientific notation) and nanometers (0.0000001, or 10^{-7}, cm). In the newer "SI" version of the metric system, we think of visible light in units of nanometers or 0.000000001 meters (10^{-9} m). In this system, the violet, blue, green, yellow, orange, and red light we know so well has wavelengths between 400 and 700 nanometers. This range is only a small part of the entire EM spectrum, so you can tell that the light we see is just a little fraction of all the EM radiation around us! By the time you get to the ultraviolet, X-ray, and gamma-ray regions of the EM spectrum, lengths have become too tiny to think about any more. So scientists usually refer to these photons by their energies, which are measured in electron volts. Ultraviolet radiation falls in the range from a few electron volts (eV) to about 100 eV. X-ray photons have energies in the range 100 eV to 100,000 eV (or 100 keV). Gamma-rays then are all the photons with energies greater than 100 keV.

★ Show me a chart of the wavelength, frequency, and energy regimes of the spectrum !

Why Do We Have to Go to Space to See All of the Electromagnetic Spectrum?



Electromagnetic radiation from space is unable to reach the surface of the Earth except at a very few wavelengths, such as the visible spectrum, radio frequencies, and some ultraviolet wavelengths. Astronomers can get above enough of the Earth's atmosphere to observe at some infrared wavelengths from mountain tops or by flying their telescopes in an aircraft. Experiments can also be taken up to altitudes as high as 35 km by balloons which can operate for months.

Rocket flights can take instruments all the way above the Earth's atmosphere for just a few minutes before they fall back to Earth, but a great many important first results in astronomy and astrophysics came from just those few minutes of observations. For long-term observations, however, it is best to have your detector on an orbiting satellite ... and get above it all!

The vertical illustration of the different regions of the EM spectrum and their common uses was done by Design at Work for the curriculum supplement "Human Physiology in Space" by Barbara F. Lujan and Ronald J. White, 1994. Used by permission.